(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 710 853 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.05.1996 Bulletin 1996/19

(51) Int. Cl.[6]: **G01S 13/75**, G01S 13/76, G06K 7/10

(21) Application number: **95203435.3**

(22) Date of filing: **06.02.1990**

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB IT LI LU NL SE

(30) Priority: **17.02.1989 AU PJ2800/89**

(62) Application number of the earlier application in accordance with Art. 76 EPC: **90902977.9**

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Remarks:
This application was filed on 12 - 12 - 1995 as a divisional application to the application mentioned under INID code 62.

(54) Transponder system

(57) An interrogator (1) for an identification and telemetry system comprises: a transmitter (2) containing an antenna (3) for transmitting an interrogation signal incorporating modulated radio frequency energy at an interrogation frequency; means (36, 37, 38, 39) for generating said interrogation signal connected to said antenna (3); an antenna (3) for receiving a complete label reply signal from a signal responding label (4) containing an oscillator (9); means (40) for separating the interrogation and reply signals; means (42) for transmitting the separated reply signal to a receiver (12); and means (13, 48) within the receiver for decoding the reply signal; wherein said radio frequency energy includes a waveform having a period of substantially uniform amplitude; said oscillator (9) is used for forming said reply signal and said period is sufficient to allow coherent operation of the oscillator (9) within the label (4) for a period sufficient for the label (4) to transmit at least one complete label reply.

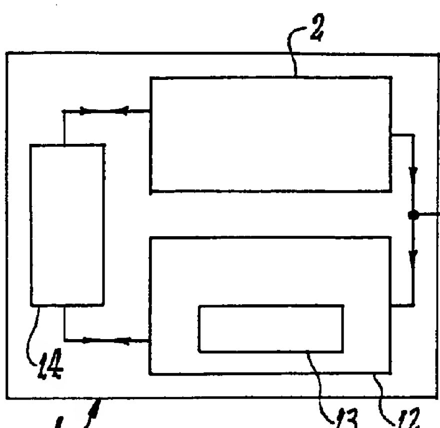

FIG 1A

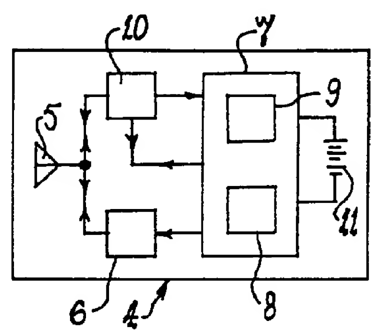

FIG 1B

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Description

The present invention relates to a Transponder System. In particular the invention relates to remote identification and telemetry systems wherein an electronic sub-system called an interrogator including a transmitter and receiver extracts by electromagnetic means useful information from an electronically coded label attached to a person or object about which information is desired.

A block diagram of a type of system to which the invention relates is shown in accompanying Figs. 1A and 1B. This system uses the principle of radio frequency backscatter in which an interrogator containing a transmitter radiates an electromagnetic signal via an interrogator antenna toward an electronic label containing a label antenna. As a consequence of electromagnetic coupling between the label antenna and the interrogator antenna, the label receives a portion of the radiated signal. In the label, the impedance of a termination connected to the label antenna may be varied in time under control of a modulator containing an electronic code generator, with the result that electromagnetic energy received by the label antenna is both partially reflected by the termination and re-radiated by the label antenna in a time varying manner. As a further result of the electromagnetic coupling between the label antenna and the interrogator antenna, a portion of the time varying radio frequency signal scattered by the label may enter a receiver included within the interrogator wherein it may be separated from the transmitted signal, amplified, decoded in a decoder and presented in digital or analog form to other systems which may make use of the information obtained by the interrogation.

In the label, operations of the code generator and variable termination may be controlled in time by an oscillator. In a passive label the circuits within the modulator may receive power for their operation from a rectifier circuit, while in an active tag they may receive at least part of their operating power from a separate battery. When the rectifier circuit is present, the effects of the time varying termination can be provided by the rectifier circuit itself, in which variation of dc load directly presented to the rectifier by the modulator may cause a corresponding variation in the load presented by the rectifier to the label antenna.

In the interrogator, there may generally be provided a controller which may perform various calculation and control functions and may also participate in the decoding process.

Practical applications of such labelling and interrogation systems lie in identification of, and or monitoring condition of, such things as persons, goods, shipping containers, pets and livestock. In the latter case, the tags are sometimes attached to the exterior of the animal, and are sometimes implanted beneath the skin.

In the practical design of such systems various problems arise. In a passive tag, one problem is that of obtaining from the rectifier circuit sufficient voltage for operation of the modulator circuits within the label at a transmitter power level sufficiently low to meet licensing, economic or health requirements.

Another problem, which applies to both active and passive tags implanted beneath the hide of animals, derives from reflection of electromagnetic fields at the animal surface, and attenuation of those fields as they propagate into the interior. This reflection and attenuation serves to reduce strength of the electric field which reaches the label antenna, with the result that power available to operate the electronic circuit within the label and to provide re-radiated power is reduced.

A further problem, applying principally to passive labels, derives from significant variation in strength of the electromagnetic field normally experienced by a label as it moves throughout an electromagnetically scanned area. For the types of oscillator circuit which it is practicable to use in miniaturised integrated electronic labels, this variation of field strength and hence rectified dc voltage causes significant consequential variation in frequency of the on-chip oscillator which controls generation of the reply code. Since almost all forms of reply signal encoding employ time as an important parameter, such variation can cause difficulties or errors in decoding, or require that a significant portion of the information in the reply be devoted to the task of indication of frequency of the on-board oscillator. In normally used forms of reply signal decoding, circuits in the receiver must firstly detect the frequency of the modulation signal used in constructing a reply, and after this frequency is detected, determine reply signal information content. If the label is, by virtue of its motion, only exposed to the interrogation signal for a limited period, a portion of which is used in frequency determination, the amount of useful information which is recoverable from the label is limited by the problem discussed.

Although this problem can be alleviated to a degree by use of a voltage regulator within the label, the label rectifier system must then supply the sum of the voltage drop required across the regulator for satisfactory operation and the minimum operating voltage for the oscillator circuit, with the result that an effective reduction in label interrogation range occurs.

A further problem, which affects labels being read at all but very short distances, is that the reply signal reaching the interrogator antenna is very weak in relation to the interrogation signal and yet occupies a very similar region of the frequency spectrum. The usual technique for separation of the reply from the interrogation signal involves firstly use of a circulator or directional coupler to effect gross separation of signals flowing in the forward and reverse directions in the interrogator antenna transmission line, and then use of linear signal mixing to move the reply signal to a lower frequency band, wherein amplification and filtering may be conveniently applied.

In the gross separation discussed above, effectiveness depends upon the degree of isolation which may be achieved by the coupler or circulator, and also on the extent to which the interrogator antenna is matched to its transmission line, any imperfections in antenna

matching having the same effect as imperfect isolation in the coupler or circulator. If insufficient matching is achieved, the mixer which effects frequency conversion of the reply signal will become overloaded by the imperfectly removed interrogation signal, and will not function properly. The result is that extremely accurate interrogator antenna matching is required for successful system operation at large interrogation ranges. Such extremely accurate matching cannot normally be sustained in the face of typically encountered changes in antenna environment, so the hoped for interrogation range is not achieved, even though the reply signal be well above both thermal noise and the level of other stray reflected signals in its passband.

A further problem is present in homodyne detection systems normally used for detection of the reply signal. In such systems a low power version of the transmitted signal is used in the interrogator receiver as the local oscillator for the linear mixer which transforms the reply signal to the previously said lower frequency band. Because the reply is derived by direct modulation within the tag of the transmitted signal, there will be phase coherence between the reply and the local oscillator derived from the transmitter. The result will be that the mixer will produce zero baseband output whenever the reply is in quadrature with the local oscillator, as indeed it will be whenever the difference in propagation time from the transmitter to mixer, via the tag and via the local oscillator sampling path, is a quarter of a period of the transmitter oscillation. Because in a radio frequency backscatter system the phase of the reply varies considerably as the label moves within the scanned area, this effect will produce positions of the label for which no reply is observed.

The usual way in which this problem is met is to divide the reply signal into two portions, each being fed to a separate mixer, the two mixers having local oscillator signals derived from the transmitter but with a ninety degree relative phase shift, the mixer outputs being again combined to a single data stream after one of them has been provided with a further ninety degree phase shift at the baseband frequency. Although this remedy does produce a form of baseband signal for all positions of the label, the baseband signal so obtained contains distortion which may prejudice successful decoding unless the spectrum of the signal is relatively narrowband, i.e. takes the form of a modulation signal of limited bandwidth superimposed on a significantly higher frequency sub-carrier. Since the frequency of this sub-carrier can be no greater than the frequency of the oscillator within the tag from which it is derived, and since considerations of economical use of power received by the tag set a practical upper limit to this frequency, the need in this kind of detection system to use a narrow-band modulation sets an unwelcome limit to the rate at which data may be transmitted within the reply, and a consequential limit to the amount of data which may be recovered from a label which by virtue of its motion may be within the interrogation field for only a short period of time.

Respective different aspects of the present invention are set forth in claims 1, 14, 24, 27, 33 and 36. Preferred or optional features are set forth in the subclaims.

Some embodiments of the invention provide a passive radio frequency backscatter identification and telemetry system which possesses increased interrogation range while maintaining interrogation power within acceptable limits. Some embodiments of the invention further provide a radio frequency backscatter tag or passive interrogatable label which allows convenient user coding of information content of the reply signal. The tag or label may be suitable for operation when implanted within animals and may be relatively immune to loss in sensitivity when placed in close proximity to electrically lossy objects. A radio frequency backscatter interrogation system embodying the present invention may enable reliable collection of data in the face of substantial variation in tag oscillator frequency, and may enable collection of relatively long data streams from rapidly moving objects. An identification and telemetry system embodying the present invention may permit simple detection and decoding of the reply signal.

Some embodiments of the invention may provide practical apparatus for remote identification and telemetering using electronic coded labels. An embodiment may include an electronic label with an antenna which receives radio frequency energy from an interrogation field created by the transmitter in an interrogator. Through the mechanism of modulated rf backscatter, in which the impedance connected to the label antenna may be periodically modulated by an electronic code generator circuit within the label, the label may return part of that energy in the form of a coded reply signal to a receiver in the interrogator.

The label may contain a rectifier to convert a portion of the rf signal received by the label antenna to a direct current, for the purposes either of initiating operation of or providing power for the electronic code generating circuits.

The label may contain an antenna which is designed to couple efficiently to the electromagnetic fields, in which the electric component of the field is weakened and the magnetic component is enhanced as a result of reflections at object surfaces, commonly encountered in the vicinity of practical objects to be labelled. An advantage of the use of a magnetic field responding antenna is that the effective interrogation range of the system may be increased in environments containing lossy dielectric media, such as occur when the labels are used in personnel or animal identification applications.

The effective interrogation range of the system may also be enhanced by incorporation within the label of an optimally configured rf voltage magnifying resonator circuit, which may be placed between the label antenna and the dc rectifier system, with the result that the dc output voltage for a given incident rf field may be greatly increased.

A further enhancement of interrogation range may be achieved through pulse operation of the transmitter

in the interrogator. This increase is a consequence of several factors. One is that for the label to operate correctly a certain threshold voltage must be reached in the output of the rectifier. The second is that health and radio licensing considerations limit the average power which may be used in the transmitter of the interrogator. Such pulse operation may greatly increase the operating voltage in the label for a given average operating power in the transmitter.

The interrogator of the system may contain means for improving the accuracy of decoding of replies from labels in which the oscillator frequency varies as the label moves within the often irregular interrogation field.

One method by which this may be achieved is by arranging the interrogator to capture a complete record of the label reply before an attempt to decode that reply is made. An advantage of the method of capture and decode later is that it may eliminate loss of part of the reply information which occurs in real time decoding circuits which require a period of synchronisation with the reply signal before they are effective, and hence may enable successful decoding of replies from labels which as a consequence of their motion, reside within the interrogation field for only a brief period. A further method is described below.

An embodiment of the invention may provide a compact circuit for reliable decoding of replies, containing frequency shift keying modulation, originating in practical labels in which oscillator voltage varies over reply time as a result of variation during label movement of the dc voltage developed in the label rectifier.

An embodiment of the invention may include a phase locked loop frequency decoder, together with a band-pass filter interposed between the frequency decoder and the circuit which interprets transitions in reply frequency, to recover a serial bit stream containing the reply code. An advantage of this circuit is that no special precautions to stabilise the power supply within the label may be required, and the label in consequence may operate with a smaller dc output voltage from the rectifier, and greater interrogation range results.

The interrogator may incorporate circuits for adaptive cancellation of variable reflections from non-label objects moving within the interrogator field of view. Such reflections, if not cancelled, can cause overload of sensitive detector circuits within the receiver. An advantage of cancellation of the reflections is that it may permit use of a much greater transmitter power than is otherwise practicable, with a consequent significant increase in interrogation range.

According to another aspect of the present invention there is provided a signal responding label for an identification and telemetry system and comprising:

an antenna for receiving an interrogation signal and for scattering a reply signal, an impedance connected to said antenna, means for generating said reply signal and means for varying said impedance in accordance with said reply signal.

According to a further aspect of the present invention there is provided an interrogator for an identification and telemetry system and comprising:

an antenna for transmitting an interrogation signal and for receiving a reply signal, a transmitter connected to said antenna and including a generator of pulsed radio frequency energy, means for effecting separation of said reply signal from said transmitted signal, a receiver connected to said antenna and means within said receiver for detecting and decoding said reply signal.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency antenna for receiving an interrogation signal, a voltage magnifying resonator having an impedance connected to said antenna, a rectifier system connected to the output of said resonator, means for generating a reply signal and means for varying said impedance in accordance with said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogation signal, a transmitter connected to said interrogating antenna and containing a generator of pulsed radio frequency energy, means for effecting coarse separation of said reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna, means for cancellation of residual coupling between said transmitter and said receiver, means for automatic adjustment of such cancellation, means within said receiver for separate detection of in-phase and quadrature components of said reply signal, and means for decoding the separately detected components.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency antenna for receiving an interrogation signal, an impedance connected to said antenna, means for generating a reply signal and means for varying said impedance in accordance with said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogation signal, a transmitter connected to said interrogating antenna and containing a generator of pulsed radio frequency energy, means for effecting separation of label reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna, means within said receiver for separate detection of in-phase and quadrature components of said reply signal, and means for decoding the separately detected components.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency magnetic field responding antenna for receiving an interrogation signal and for scattering a reply signal, an impedance connected to said antenna, means for generating said reply signal and means for varying said

impedance in accordance with said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogation signal, a transmitter connected to said interrogating antenna and containing a generator of radio frequency energy, means for effecting separation of said reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna and means within said receiver for detecting and decoding the signal scattered from said magnetic field responding antenna.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency antenna for receiving an interrogation signal and for producing a reply signal, a voltage magnifying resonator having an impedance connected to said antenna, a rectifier system connected to the output of said resonator, means for generating said reply signal, and means for varying said impedance in accordance with said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogating signal, a transmitter connected to said interrogating antenna and containing a generator of radio frequency energy, means for effecting separation of said reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna and means within said receiver for detecting and decoding said reply signal produced from said radio frequency antenna.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency antenna for receiving an interrogation signal and for scattering a reply signal, an impedance connected to said antenna, means for generating said reply signal and means for varying said impedance in accordance with said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogating signal, a transmitter connected to said interrogating antenna and containing a generator of radio frequency energy, means for effecting coarse separation of said reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna, means for cancellation of residual coupling between said transmitter and said receiver, means for automatic adjustment of such cancellation and means within said receiver for detecting and decoding said reply signal produced from said radio frequency antenna.

According to a still further aspect of the present invention there is provided an identification and telemetry system comprising:

a signal responding label including a radio frequency antenna for receiving an interrogation signal and for scattering a reply signal, an impedance connected to said antenna, means for generating said reply signal and means for varying said impedance so that a portion of energy incident on said radio frequency antenna is scattered therefrom at frequencies which vary from time to time in accordance with content of said reply signal;

an interrogator including an interrogating antenna for transmitting said interrogation signal and for receiving said reply signal, a transmitter connected to said interrogating antenna and containing a generator of radio frequency energy, means for effecting separation of said reply signal from said transmitted interrogation signal, a receiver connected to said interrogating antenna, means within said receiver for detecting the frequency of said signal scattered from said radio frequency antenna, means within said receiver for detecting rapid frequency changes, while ignoring slow frequency changes in said scattered signal and means for decoding the sequence of detected frequency changes.

The reply code may be derived from a non-volatile electrically programmable and erasable memory. The reply code preferably is superimposed on a sub-carrier. The sub-carrier may be phase, amplitude or frequency modulated.

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings wherein:

Figures 1A and 1B show major sub-units of an identification or telemetry system containing an interrogator and coded label;

Figures 2A and 2B show physical and circuit representations respectively of antenna and rectifier in one form of coded label;

Figures 3A and 3B show physical and circuit representations respectively of antenna and rectifier in a second form of coded label;

Figure 4 shows an internal arrangement of one form of label modulator;

Figure 5 shows an internal arrangement of a second form of label modulator;

Figure 6 shows an internal arrangement of a third form of label modulator;

Figure 7 shows a circuit representation of a third form of coded label;

Figure 8 illustrates four important functions performed within the coded label;

Fibure 9 is a block diagram of an interrogator for a coded label;

Figure 10 shows the structure of one form of baseband signal processor of an interrogator;

Figure 11 shows the structure of a second form of baseband signal processor of an interrogator, and the structure of a demodulator and decoder for a frequency shift keying encoded reply; and

Figure 12 shows the structure of an adaptive control block used in a reflection cancellation system of an interrogator.

Figure 1A shows major sub-units of an interrogator 1 containing a transmitter 2 which radiates via interrogator antenna 3 an electromagnetic signal toward an elec-

tronic label 4 shown in Figure 1B. Label 4 contains a label antenna 5. As a consequence of electromagnetic coupling between label antenna 5 and interrogator antenna 3 the label receives a portion of the radiated signal. In the label, the impedance of a termination 6 connected to label antenna 5 is varied in time under control of a modulator 7 containing an electronic code generator 8, with the result that electromagnetic energy received by label antenna 5 is both partially reflected by the termination and re-radiated by label antenna 5 in a time varying manner. As a further result of electromagnetic coupling between label antenna 5 and the interrogator antenna 3 a portion of the time varying radio frequency signal scattered by label antenna 5 enters receiver 12 included within interrogator 1 wherein it is separated from the transmitted signal, amplified, decoded in decoder 13 and presented in digital or analog form to other systems which may make use of the information obtained by the interrogation.

In the label, operations of code generator 8 and variable termination 6 are controlled in time by an oscillator 9. In a passive label circuits within modulator 7 receive power for their operation from a rectifier circuit 10, while in an active tag they receive at least part of their operating power from a separate battery 11. When rectifier circuit 10 is present, the effects of a time varying termination can be provided by the rectifier circuit itself, in which variation of dc load directly presented to the rectifier by the modulator causes a corresponding variation in load presented by rectifier circuit 10 to label antenna 5.

Interrogator 1, includes a controller 14 which performs various calculation and control functions and may also participate in the decoding process.

Figures 2A and 2B show one preferred embodiment of coded label. In Figure 2A physical aspects of some components are illustrated, while in Figure 2B, circuit aspects of the corresponding components are represented.

In the preferred embodiment shown in Figure 2A, the label contains a magnetic loop antenna (MLA) 15 connected to a rectifier circuit containing a microwave rectifier diode (MRD) 16 and dc reservoir capacitor (DCR) 17. The reservoir capacitor 17 is connected to a modulator (MOD) block 7, details of which will be described later.

In Figure 2B, circuit elements R_R and R_L represent radiation and loss resistance respectively of MLA 15, L_A represents self inductance of MLA 15, C_D represents junction capacitance of MRD 16, C_R represents capacitance of reservoir capacitor 17, and E_i represents open circuit rf voltage induced in MLA 15 by reception of the interrogation signal.

In the system illustrated in Figure 2A, MLA 15 takes the form of an electrically small, ie. dimensions much less than a wave length, inductive loop, responding to the magnetic field component of the incident electromagnetic field. The dimensions of the loop are chosen to be as large as possible, consistent with the size requirements of the label and with a requirement that the self inductance of the loop forms at the frequency of interrogation a resonant circuit with the junction capacitance of rectifier diode 16.

The use of a small magnetic field responding antenna provides several benefits. Firstly the antenna is immune to sensitivity loss when placed in close proximity to lossy dielectric media, as often occurs with labels in practice, an example being when the label is used as a personnel identification or security tag. Secondly sensitivity of the label is enhanced when it is placed in the field of an electromagnetic wave reflected from a partially-conducting or well-conducting surface, as although such reflection causes a reduction in the electric field strength close to the reflecting medium, the magnetic field in that region is enhanced. In the extreme case when the label is to be implanted beneath the skin of an animal, enhancement of the magnetic field as opposed to the very substantial reduction of the electric field when the incident wave is reflected at the animal surface, provides a great increase in label sensitivity over labels using the commonly chosen electric dipole antenna.

Use in the label illustrated in Figure 2A of a magnetic field responding antenna carries another significant benefit. The extent to which it is possible to derive by reception from the interrogation field a sufficient voltage to provide satisfactory operation of electronic circuits in the modulator, depends firstly on the received voltage of the antenna, and secondly on the extent to which this voltage may be magnified by passive circuit techniques. The optimum circuit technique is to ensure that there is resonance at the frequency of interrogation between the junction capacitance of the rectifier diode and a low loss inductor, with dynamic impedance of the resonant circuit being well matched to the radiation impedance of the antenna. The voltage magnification achieved is equal to the quality factor of the resonant circuit. The choice of a magnetic field responding antenna allows this resonance to be achieved with particularly high quality factor, and with a minimum number of additional components, with a consequent reduction both of further electrical losses and physical size and cost of the label.

In another preferred embodiment, shown in Figure 3A, the label contains an electric dipole antenna (EDA) 18 connected to a rectifier circuit, again containing a microwave rectifier diode (MRD) 16 and dc reservoir capacitor (DCR) 17. Reservoir capacitor 17 is again connected to a modulator (MOD) block 7, the detail of which will be described later. The connection between EDA 18 and rectifier 16 this time contains an antenna matching inductor (AMI)20.

In Figure 3B, circuit elements R_R and R_L again represent radiation resistance and loss resistance of EDA 18, L_A and C_A represent frequency behaviour of EDA reactance, L_M represents inductance of the matching reactance, L_R represents inductance of the resonating reactance, C_D again represents junction capacitance of MRD 16, C_R again represents capacitance of reservoir capacitor 17 of the rectifier, and E_i again represents open

circuit voltage induced in EDA 18 by reception of the interrogation signal.

In the system illustrated in Figure 3A, EDA 18 may take the form of either an electrically large or small electric dipole. The dimensions of this antenna are normally chosen to be as large as possible consistent with size requirements of the label, and when a large antenna can be used the benefits of wide bandwidth and consequential relative immunity to detuning are realised.

Passive voltage magnification is in this embodiment realised through provision of resonating inductor 19 of which inductance L_R forms at the frequency of interrogation a resonant circuit with the junction capacitance of the rectifier diode. The functions of matching inductor (AMI) 20 are firstly to provide a dc return for the rectifier circuit, and secondly to ensure that radiation impedance of EDA 18 is well matched to the dynamic impedance of a voltage magnifying circuit. An important characteristic of the passive voltage magnifying circuit is that the stored electric energy of the resonance process is substantially that present in the diode junction capacitance. This is the condition for optimum passive voltage magnification with an electrically large antenna.

Figure 4 shows one preferred embodiment of label modulator 7. It contains a self contained oscillator (OSC) 9, a level sensitive detector (LSD) 21, a multiplexer address counter (MAC) 22, and a multiplexer code generator (MCG) 23, with inputs which are either left open or tied low to provide a digital one or zero respectively in the code, and a digitally controlled load (DCL) 24.

The label modulator comes into operation when the output voltage from the rectifier system 10 is sufficient to produce regular oscillations from the oscillator block 9, and also to cause the single bit digital output of level sensitive detector 21 to take a high state. When these conditions are met, multiplex address counter 22 cycles sequentially through all address states, so that the multiplexer samples in order all inputs, and produces at its output a cyclic repetition of the reply code programmed at those inputs. So that the code is produced without error, the threshold of operation of level sensitive detector 21 is set to a value at which reliable operation of the oscillator, counter and multiplexer circuits is assured. The output of the multiplexer code generator 23 is connected to a digitally controlled load 24, which provides the required variation in load presented to rectifier circuit 10 within the label.

In this modulation scheme, the multiplexer may provide simple amplitude modulation of the rf signal scattered by the label, or may if given a number of inputs substantially in excess of the number of bits to be encoded, implement a number of different modulation schemes including frequency shift keying and amplitude or phase modulation of a sub-carrier. Such modulation schemes are to be preferred to simple baseband modulation, as they suffer less in detection of replies from background clutter generated by naturally occurring objects in the field of view of the interrogator. Such modulation schemes can be generated by means other than that just described, most usually through interposition of an additional functional block between multiplexer code generator 23 and the digitally controlled load 24. Design of such functional blocks is a matter of ordinary skill and is not discussed here.

In generation of information to be contained within the reply code, some multiplexer inputs may be committed to the provision of identity information through being permanently either tied low or left open, while some may be connected to other circuits which provide in a telemetry application variable information. An example would be provided by connection, to one of the multiplexer inputs in an implanted animal label, of an output of a comparator of which the input is connected to a resistance bridge containing a thermally sensitive resistor. Such a label could provide an indication of animal indentity together with a single-bit indication of animal health. An obvious alternative method of including telemetry information is to make the frequency of the oscillator 9 an information bearing parameter. An example is provided by an implanted animal label in which natural temperature dependence of certain designs of oscillator circuit may be used to indicate animal temperature.

Figure 5 shows another preferred embodiment of modulator 7. It substitutes an electrically programmable and erasable memory (EPM) 25 for the previously discussed multiplexer code generator 23, but in other ways resembles the structure shown in Figure 4.

Figure 5 also shows a possible realization of digitally controlled load 24 in the form of a field effect transistor 26 with current limiting resistor 27. By appropriately proportioning transistor 26 and resistor 27, an impedance vs voltage characteristic matching the characteristic of the dc supply output impedance vs voltage level over a suitable range of power level may be achieved.

Programming of memory 25 is achieved through programming interface (MPI) 28, which may accept external programming signals either by direct connection or appropriate non-contact electromagnetic coupling means.

Figure 6 shows another preferred embodiment of modulator 7, suited to efficient generation of a reply signal with frequency shift keying modulation.

In this embodiment oscillator 9 runs at a rate significantly greater than either of the modulation frequencies, and is counted down by programmable digital counter (PDD) 29, which may effect under control of a mode control signal MCS a count of either eight or ten. As well as being fed to digitally controlled load 25 to effect modulation of antenna impedance, the output of divider 29 is fed to the clock input of a similar programmable digital divider 30, of which the mode control input is the complement of that reaching divider 29. The result of these connections is that the combined count of both dividers is always a factor of eighty, and the output of the second divider can provide a constant bit rate signal which is used as described in the paragraph below.

The output of divider 30 is used as a clock signal for multiplexer address counter (MAC) 22, the output of

which, as in the modulator of Figure 4, cycles sequentially through all address states, so that multiplexer code generator (MCG) 23 again samples in order all inputs, which are either left open to represent a one or tied low to represent a zero, and produces at its output a cyclic repetition of the reply code programmed at those inputs. The output of multiplexer code generator 23 is used as the mode control signal MCS of counter 29, and is complemented by inverter 26 to provide the mode control signal of counter 30.

The overall effect of the modulator is to produce a frequency shift keying modulation signal with modulation frequencies equal to the oscillator frequency divided by either eight or ten, and a bit period equal to eighty times the period of oscillator 9.

Figure 7 shows another preferred embodiment of label in which the label again contains an electric dipole antenna (EDA) 18 of which the circuit representation is shown. EDA 18 is connected to a rectifier circuit, again containing a microwave rectifier diode (MRD) 16 and dc reservoir capacitor (DCR) 17. In this embodiment reservoir capacitor 17 is again connected to modulator 7, but the dc output voltage developed in capacitor 17 serves only to activate timed control switch (TCS) 34, which connects for a period of time after the said dc voltage is detected, power from battery 11 to oscillator (OSC) 9 and electronic code generator (ECG) 8.

Because power for operation of those circuits comes from a battery, and the rectifier system is required only to provide the negligible power required to initiate opening of the control switch, the quality factor and hence voltage magnification of the tuned circuit containing the rectifier capacitance can be higher than in the previously discussed designs. The result is a significant increase in interrogation range for the label.

In accord with the different use in this embodiment of label of the dc voltage from the rectifier, modulation of the antenna terminating impedance is provided directly through control of antenna termination 6, rather than through modulation of the impedance connected to the rectifier. Components comprising the controllable antenna termination are PIN diode 31, bypass capacitor 32 and rf isolation inductor 33. After modulation is applied, the timed control switch derives its operating power from battery 11. This direct control of the antenna terminating impedance can produce very efficient rf backscatter signal generation.

Figure 8 shows important fuctional charcteristics of the label circuits illustrated in Figures 2B, 3B and 7, and may be used to better explain the operation of those circuits. In each of the embodiments shown in those figures, the label contains a label antenna 5, a voltage magnifying resonator 35, a rectifier and filter 10, and a modulator 7.

Several characteristics of these functional blocks may be noted. The first is that the physical elements which provide the indicated functions are in some cases shared between blocks. Examples of this sharing include the self inductance of the magnetic antenna loop in Figure 2B which provides the resonating inductance of the voltage magnifying resonator, and the microwave diode in Figures 2B, 3B and 7 which provides both the resonating capacitance of the voltage magnifying resonator, and the unidirectional current element of the rectifier and filter. The second is that the electrically important circuit element is in one case the aberrant (stray) rather than the principal characteristic of the circuit device used. This statement refers to the voltage magnifying resonator, in which the electrical energy storage element is the junction capacitance of the rectifier diode.

It is the characteristics just mentioned which provide for maximisation in each of the three embodiments of passive voltage gain of the circuit, and consequent maximisation of interrogation range for given interrogation power.

In practical application of principles outlined in relation to Figures 2, 3 and 7, it is necessary to take into account the fact that diode junction capacitance depends on excitation level, and to adjust the size of the resonating inductance L_A or L_R for a desired operating signal level in the label.

In the design of efficient voltage magnifying resonators, it is sometimes convenient to use distributed circuit elements such as strip line or cavity resonators. Although in such cases electric energy stored within the resonator may no longer be substantially that within the junction capacitance of the rectifier diode, the higher quality factor of dynamic energy storage obtained with distributed circuit elements still allows substantial voltage magnification.

Figure 9 shows a block diagram of one preferred embodiment of interrogator. The interrogation signal has its origin in radio frequency transmitter master oscillator (TMO) 36, which is pulse modulated by means of double balanced mixer (DBM) 37, of which the control input is derived from transmitter pulse generator (TPG) 38. The modulated output of miser 37 is applied to transmitter power amplifier (TPA) 39, and is conveyed to interrogator antenna 3 by means of signal sampling directional coupler (SSC) 40 and double screw tuner (DST) 41, the function of which will be described shortly.

There is an important practical consequence of the use of pulse modulation in the transmitter output signal, in that modulation with an appropriate duty cycle allows a significant increase in peak transmitter output power, while average output power still remains within limits set by radio licensing and health requirements. This increase in output power allows the dc voltage required to operate the label circuits to be developed at significantly greater interrogation range, or with labels in unfavourable interrogation situations such as implanted within tissue. Since data rates at which rf backscatter labels reply are normally much greater than achieved with low frequency transponders, interrogation pulses can be made sufficiently short and hence interrogations sufficiently frequent to enable data retrieval from even rapidly moving objects. Pulse operation of the transmitter

also reduces power dissipation and heat generation in interrogator electronics.

As is clear from the discussion of the preferred embodiment, shown in Figure 4, of the functions of the label modulator 7, self contained oscillator (OSC) 9, multiplexer address counter (MAC) 22 and multiplexer code generator (MCG) 23, the length of the interrogation pulse should, in a system using pulsed interrogation and that embodiment of label modulator, be sufficient to produce coherent oscillations from the oscillator block for a period of time sufficient for the label to produce at least one complete reply.

The reply signal which is received from the label via the interrogator antenna 3 is separated from the transmitted signal by signal sampling directional coupler 40, and conveyed via the main line of a signal injection coupler (SIC) 42, to a power splitter (PWS) 43, wherein it is divided into two paths and reticulated to the signal ports of doubly balanced mixers (DBM) 44 and 45. The local oscillator ports of those mixers are fed from transmitter master oscillator 36 via power splitter (PWS) 46, with one of the signals emergent from splitter 46 being subject to a ninety degree phase shift in quadrature phase shifter (QPS) 47. Outputs IBS and QBS of balanced mixers 44 and 45 therefore represent in-phase and quadrature components of the signal received by the interrogator, translated downward by an amount equal to the interrogation frequency. The outputs IBS and QBS of signal mixers 44, 45 are fed to baseband processor and decoder (BPD) 48, from which the decoded reply is determined by means to be explained later.

The function of double screw tuner 41 can now be explained. Its principal purpose is to prevent overload of signal ports of balanced mixers 44 and 45 from occurring either through imperfect matching of interrogator antenna 3 to its transmission line, or through the existence in practice of imperfect directivity in signal splitting coupler 40. Appropriate adjustments of tuner screws can produce reflections which can cancel unwanted coupling which can arise from either of the mechanisms just mentioned between transmitter power amplifier 39 and receiver mixers 44 and 45, with the result that quite high transmitter powers can be used before those mixers become overloaded.

Such adjustment, which is normally manually performed during assembly and test of the interrogator, using observation of the waveform present at the outputs QBS and IBS of mixers 44 and 45 respectively as the adjustment criterion, is of considerable benefit in enhancing receiver sensitivity, but cannot remain fully effective in the face of variations in antenna reflection factor which occur as a result of objects moving in the field of interrogator antenna 3. Significant improvement in interrogator sensitivity may be achieved in the face of such variation if cancellation of unwanted coupling is made self-adjusting.

For this purpose, a portion of transmitter power is sampled by means of a further port of signal splitting coupler 40, and fed to power splitter (PWS) 49. The two equal amplitude outputs of power splitter 49 are recombined in power combiner (PWC) 50 after each has experienced some attenuation in one of the voltage controlled attenuators (VCA) 51 or 52, and one of them has been subject to a ninety degree phase shift in quadrature phase shifter (QPS) 53. The output of power combiner 50 is re-inserted into the reply signal chain by means of previously mentioned signal injection coupler 42.

The effect of the system just discussed is that means are provided to cancel, within amplitude limits, a residual transmitter antenna mismatch of any amplitude and phase.

So that this reflection can be automatically adjusted, the control signals for the voltage controlled attenuators are derived by means of an adaptive control block (ACB) 54, which takes its inputs from the in-phase and quadrature reply signal mixers 44 and 45, and from the transmitter pulse generator 38, and determines between each interrogation pulse the voltages required to be fed to control ports of voltage controlled attenuators 51 and 52.

Figure 10 shows a block diagram of one preferred embodiment of baseband processor and decoder 48. In this embodiment baseband signals IBS and QBS from receiver mixers 44 and 45 are first amplified in band pass amplifiers (BPA) 55 and 56, with amplitudes of the signals being detected in signal amplitude detectors (SAD) 57 and 58. The function of signal amplitude detectors 57, 58 is to allow detection of when a reply signal is being received from a label, so that a record of the reply can be made for later decoding. To accomplish this detection, the outputs of signal amplitude detectors 57 and 58 are combined in OR gate 59, the result RTE being fed to microprocessor (µP) 60 which controls operations within the baseband processor and decoder.

When the occurrence of a reply is so detected, a digital record of the reply signal in both in-phase and quadrature channels is made and is stored within the memory of microprocessor 60. The digital representation of the reply is prepared by fast analog to digital converters (ADC) 61 and 62, operating under control of sampling timing system (STS) 63, which generates when required the sequence of memory address and control signals required to place regularly obtained digital samples of band pass amplifier 55, 56 outputs into memory blocks (ISS) 64 and (QSS) 65. A series of tri-state buffers (TSB) 66 allow the same memory blocks to be placed when required directly within microprocessor 60 address space.

Decoding operations performed within this baseband processor and decoder are performed by software, within microprocessor 60, in the time intervals between interrogator pulses, after each record of the reply has been completed, the period of each interrogation pulse being sufficient for collection of a complete reply. Advantages of performing decoding in this way are that complex signal recovery from noise algorithms may be used, that decoding can deal with signals of large fractional bandwidth, that irregularities in the reply may be flexibly detected and discounted, and that no part of the reply is

lost in initial synchronisation between the reply signal and real time decoding circuits which may have been used as an alternative.

The reply signal when decoded is available whenever required via serial interface (SIO) 67 of microprocessor 60.

Figure 11 shows a block diagram of another preferred embodiment of baseband processor and decoder 48. As in Figure 10, this circuit provides band pass amplifiers (BPA) 68 and 69 for outputs IBS and QBS from receiver mixers 44 and 45. For the amplified baseband signals, signal amplitude detectors (SAD) 70 and 71, the outputs of which are combined in OR gate 72 to produce reply threshold exceeded signal RTE, are again provided.

The balance of the processing however differs considerably from that described in relation to Figure 10. In the present embodiment, the reply signal generation scheme used in the labels is assumed to produce a reply signal modulation superimposed on a sub-carrier, and amplified mixer output signals are assumed to be of small fractional bandwidth. These signals are combined, after amplification and after the quadrature signal has been subject to a further ninety degree phase shift in quadrature phase shifter (QPS) 73, in difference amplifier 74. The composite baseband signal CBS produced by difference amplifier 74 is fed together with the RTE signal to demodulator and decoder (DAD) block 75.

The contents of demodulator and decoder block 75 depend on the form of modulation employed within the label to provide an expression of the reply code. The present example shows the components which will accomplish real time demodulation and decoding of signals encoded by frequency shift keying. These components consist simply of a standard frequency shift keying decoder circuit (FSD) 76, such as the EXAR XR-2211, incorporating a zero crossing detector 77, and operating in conjunction with a band pass or low pass filter 78 and simple microcontroller (μC) 79, such as a Motorola MC68HC11.

In operation of this circuit, FSK decoder 76 produces at its first output a waveform proportional to reply modulation frequency. This waveform is subject to band pass or low pass filtering, in filter 78, and the filter output is applied to zero crossing detector 77, which produces the second output of decoder 76. Microcontroller 79 recognizes transitions in voltage level of the waveform produced by detector 77, and decodes the serial bit stream so found. The decoded reply resides in microcontroller memory, and emerges, when called for, from the serial port of that device.

An advantage of use of frequency shift keying in the label, and a phase locked loop frequency shift decoder in the interrogator, is that they together provide a very compact decoding process for reply modulation. The reply signal frequency is by this means readily converted to an equivalent voltage as the phase locked loop simply tracks variations in label oscillator frequency, even when that frequency varies over a significant range due to variations in label rf excitation level and hence rectified dc supply voltage.

The advantage of use of band pass filtering in the demodulation process just discussed is that slow variations in label oscillator frequency caused by variation in dc voltage developed in the label rectifier circuit as the label moves within the interrogation field will not cause error in interpretation of information content of the reply.

Although Figure 11 shows as contents of the demodulator and decoder block, components which are appropriate to an FSK modulation produced in the label, other simple contents can be used for other forms of modulation.

Figure 12 shows detail of one embodiment of adaptive control block 54 of the interrogator. The input signals are baseband signals IBS and QBS from receiver mixers (DBM) 44 and 45. These signals are stripped of their dc component, which can arise from interaction of local oscillator excitation and imperfect balance of the mixers, by capacitors 80 and 81. Transmission gates (BSG) 82 and 83 operating under control of transmitter enable pulse TEP, subsequent amplifiers (LPA) 84 and 85, and analog to digital converters (ADC) 86 and 87 ensure that at the end of each transmission period, digital representations of mixer outputs during transmitter-on period are available to microcontroller (μC) 88. During the period between transmissions, microcontroller 88 makes a calculation of required adjustment in control signals for voltage controlled attenuators (VCA) 51 and 52 in the receiver, and generates fresh values of those signals by means of digital to analog converters (DAC) 89 and 90, for presentation to attenuators 51 and 52 before the next transmission period.

It will be appreciated that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the scope of the present invention.

Claims

1. An interrogator (1) for an identification and telemetry system, said interrogator (1) comprising:

   a transmitter (2) containing an antenna (3) for transmitting an interrogation signal incorporating modulated radio frequency energy at an interrogation frequency; means (36, 37, 38, 39) for generating said interrogation signal connected to said antenna (3); an antenna (3) for receiving a complete label reply signal from a signal responding label (4) containing an oscillator (9); means (40) for separating the interrogation and reply signals; means (42) for transmitting the separated reply signal to a receiver (12); and means (13, 48) within the receiver for decoding the reply signal;

   wherein said radio frequency energy includes a waveform having a period of substantially uniform amplitude; said oscillator (9) is used for forming said reply signal and said period is sufficient to allow

coherent operation of the oscillator (9) within the label (4) for a period sufficient for the label (4) to transmit at least one complete label reply.

2. An interrogator as claimed in claim 1, wherein the interrogation signal is pulse modulated.

3. An interrogator as claimed in claim 2, wherein the envelope of the interrogation signal is shaped so that the power which is transmitted during said period is as large as possible subject to a need to satisfy regulations which limit peak power, average power, and peak to average power ratio in the interrogation signal.

4. An interrogator as claimed in claim 2, wherein the duration of an interrogation pulse and of the label reply are made sufficiently short, and occurrence of interrogation pulses is made sufficiently frequent, to enable data retrieval from rapidly moving objects.

5. An interrogator as claimed in claim 1, wherein said label contains a rectifier (10) including a diode (16) and providing at least part of the power required in forming said reply signal.

6. An interrogator as claimed in claim 5, wherein said receiver (12) contains means (68, 69, 73, 76, 77, 78) for detecting rapid frequency changes, while ignoring slow frequency changes, in said reply signal, and means (13, 79) for decoding the sequence of detected frequency changes.

7. An interrogator as claimed in claim 6, wherein said means for detecting rapid frequency changes, while ignoring slow frequency changes, comprises a phase locked loop.

8. An interrogator as claimed in claim 7, wherein said reply signal comprises a reply code superimposed on a sub-carrier.

9. An interrogator as claimed in claim 8, wherein said sub-carrier is frequency modulated.

10. An interrogator as claimed in claim 1, wherein an interrogation antenna (3) is used as the transmitting antenna and the receiving antenna.

11. An interrogator as claimed in claim 1, including means (41) for cancelling residual coupling between said transmitter (2) and said receiver (12).

12. An interrogator as claimed in claim 11, including means (49, 50, 51, 52, 53, 54) for automatically adjusting said cancellation.

13. An interrogator as claimed in claim 12, wherein said interrogation signal is pulse modulated to form interrogation pulses, and automatic adjustment is performed between said interrogation pulses.

14. An interrogator (1) for an identification and telemetry system, said interrogator (1) comprising:

a transmitter (2) containing means (36, 37, 38, 39) for generating an interrogation signal including a modulated waveform having a period of substantially uniform amplitude; an antenna (3) connected to said transmitter (2) for transmitting the interrogation signal supplied by the transmitter (2); an antenna (3) for receiving, from a signal responding label (4) including an oscillator (9) a label reply signal; said oscillator (9) being used in forming the reply signal; said period being sufficient to allow coherent operation of said oscillator (9) for a period sufficient for the label to transmit at least one complete said reply signal; separation means (40) for effecting coarse separation of said reply signal from said interrogation signal; a receiver (12) connected to said separation means (40); an auxiliary coupling channel (40, 49, 50, 42) to feed a portion of the interrogation signal directly to the receiver (12) wherein it is combined with the reply signal emerging from said separation means (40), adjustment means (51, 52) for control of the amplitude and phase of the interrogation signal emerging from the auxiliary coupling channel; and measurement means (43, 44, 45) for determining the amplitude and phase of the combined signal at the interrogation frequency reaching the receiver.

15. An interrogator as claimed in claim 14 including an adaptive control block (54) connected to said measurement means for producing control signals for said adjustment means (51, 52), said control block (54) being adapted to minimise direct coupling between said transmitter (2) and receiver (12) so as to optimise performance of the receiver (12).

16. An interrogator as claimed in claim 15, wherein an objective of the optimisation is simultaneous reduction in the amplitude of the signal at the interrogation frequency reaching the receiver (12), and reduction in the amount of noise, originating in the transmitter (2) of the interrogator (1) and at sideband frequencies used by the reply signal, which reaches the receiver (12).

17. An interrogator as claimed in claim 16, wherein the pass band of the auxiliary coupling channel is matched in its variation in amplitude and phase, relative to a centre value of the pass band, to corresponding behaviour of unwanted coupling between the transmitter (2) and receiver (12) arising from imperfections in said coarse separation means (40) or from coupling between separate transmitter and receiver antennas.

18. An interrogator as claimed in claim 17, wherein said matching is achieved by use of broad band components in the antenna and duplexer systems of the interrogator (1).

19. An interrogator as claimed in claim 14, wherein said modulated waveform has during said period a first amplitude and has during a further period a second and lesser amplitude; and the signal level at the interrogation frequency reaching the receiver is estimated by examining the mixer output, even when mixers with imperfect isolation between the local oscillator input and mixer output are used.

20. An interrogator as claimed in claim 19, wherein the interrogation signal is pulse modulated.

21. An interrogator as claimed in claim 14 wherein said separation means (40) for effecting coarse separation of said reply signal from said interrogation signal comprises a directional coupler (40).

22. An interrogator as claimed in claim 14 wherein said separation means for effecting coarse separation of said reply signal from said interrogation signal comprises a circulator.

23. An interrogator as claimed in claim 14 wherein said separation means for effecting coarse separation of said reply signal from said interrogation signal comprises separate transmitter and receiver antennas.

24. An interrogator (1) for an identification and telemetry system, said interrogator (1) comprising:

an antenna (3) for transmitting an interrogation signal including radio frequency energy, said radio frequency energy including a modulated waveform having a period of substantially uniform amplitude; means (36, 37, 38, 39) for generating said interrogation signal connected to said antenna (3); an antenna (3) for receiving from a signal responding label (4) an analog reply signal containing information, said period being sufficient to receive from the label a complete said reply signal; and means (40) for separating the interrogation and reply signals; wherein said interrogator (1) includes first means (45) for converting a component of the analog reply signal which is in phase with the interrogation signal to a lower frequency band to create a first low-frequency channel (IBS) ; second means (44) for converting a component of the analog reply signal which is in quadrature with the interrogation signal to a lower frequency band to create a second low-frequency channel (PBS); separate means (48) for extracting said information from each of those channels; and means for reporting one of them as the result of the interrogation.

25. An interrogator as claimed in claim 24 including means (68, 69, 73, 76, 77, 78) for detecting, within the reply signals in each of the in-phase and quadrature channels, rapid frequency changes while ignoring slow frequency changes.

26. An interrogator as claimed in claim 24, wherein the information extracted from the signals in each of the two channels includes an indication of the quality of the label reply or of the extraction process.

27. An interrogator (1) for an identification and telemetry system, said interrogator (1) comprising:

an antenna (3) for transmitting an interrogation signal incorporating modulated radio frequency energy at an interrogation frequency, said radio frequency energy including a modulation waveform having during a first period a first and substantially uniform amplitude and during a second period a second and lesser amplitude; means (36, 37, 38, 39) connected to said antenna (3) for generating said interrogation signal; an antenna (3) for receiving from a signal responding label (4), during said first period, an analog reply signal containing information and forming a complete reply message; means (40) for separating the interrogation and said analog reply signals; means (44, 45) for converting said separated analog reply signal to a lower frequency band; and means (48) for processing the separated analog reply signal to extract the label reply information, wherein the first period is sufficient to receive from the label a complete reply message, and said processing means (48) includes: means (63) for sampling the converted analog reply signal at a rate sufficient to detect significant components thereof; means (61, 62) for further converting the sampled values of the lower frequency band signal to digital form; means (64, 65) for storing the converted sampled values to create a digital record of the analog reply signal received during the first period, said digital record including the complete label reply message; and means (13, 48, 60) for decoding the stored sampled values during the second period to extract said label reply information from said record.

28. An interrogator as claimed in claim 27 wherein the waveform of the label is repeated cyclically as long as a relatively high power level of the interrogation signal is received by the label, and wherein reply generating means (8) within the label is arranged to insert a unique data word within the reply signal to indicate the start of message, and the decoding means (13, 48, 60) is arranged to detect, from the record of the cyclically repeated reply waveform, the start of message.

29. An interrogator as claimed in claim 27, wherein shaping of the interrogation signal envelope is such

as to have zero amplitude during said second period.

30. An interrogator as claimed in claim 1, 24 or 27 wherein said means (40) for separating the interrogation and reply signals comprises a directional coupler (40).

31. An interrogator as claimed in claim 1, 24 or 27 wherein said means for separating the interrogation and reply signals comprises a circulator.

32. An interrogator as claimed in claim 1, 24 or 27 wherein said means for separating the interrogation and reply signals comprises separate transmitter and receiver antennas.

33. An interrogator (1) for an identification and telemetry system, said interrogator (1) comprising:

an antenna (2) for transmitting an interrogation signal incorporating amplitude modulated radio frequency energy at an interrogation frequency, said radio frequency energy including a modulation waveform having during a first period a first amplitude and during a second period a second and lesser amplitude; means (36, 37, 38, 39) connected to said antenna for generating said interrogation signal; an antenna (3) for receiving from a signal responding label, during said first period, an analog reply signal containing information and forming a complete reply; means (40) for separating the interrogation and said analog reply signals; means (44, 45) for converting said separated analog reply signal to a lower frequency band; and means (13, 48, 60) for processing the separated analog reply signal to extract the label reply information, wherein the first period is sufficient to receive from the label the complete reply, and said converting and processing means includes: first means (45) for converting a component of the analog reply signal which is in phase with the interrogation signal to a lower frequency band to create a first base band channel; second means (44) for converting a component of the analog reply signal which is in quadrature with the interrogation signal to a lower frequency band to create a second base band channel; separate means (63) for sampling the converted analog reply signals in the first and second base band channels, at a rate sufficient to detect significant frequency components thereof; means (61, 62) for further converting the sampled values to digital form; means (64, 65) for storing the converted sampled values to create separate digital records of the in-phase and quadrature components of the analog reply received during the first period; and means (13, 48, 60) for extracting said information during the second period by separate filtering and decoding of the stored sampled values in each of the two separate digital records; and means for reporting one of them as the result of the interrogation.

34. An interrogator as claimed in claim 33, wherein decoding for each channel includes checking for irregularities in the reply in that channel.

35. An interrogator as claimed in claim 33, wherein shaping of the interrogation signal envelope is such as to have zero amplitude during said second period.

36. An identification and telemetry system comprising:

a signal responding label (4) including a label antenna (5, 15, 18) for receiving a modulated interrogation signal at an interrogation frequency and for scattering a reply signal; a generator (8) of said reply signal; a termination impedance (6) connected to said antenna and means (7) for varying the termination impedance in accordance with said reply signal; an oscillator (9) used in forming said reply signal; a rectifier system (10) containing a diode (16) and providing at least part of the power required by said generator, and

an interrogator (1) including a transmitting antenna (3) for transmitting said interrogation signal, said interrogation signal containing a modulation waveform having a period of substantially uniform amplitude, a transmitter (2) connected to said transmitting antenna (3) and containing a generator (36) of radio frequency energy, a receiving antenna (3) for receiving said label reply signal; means (40) for separating the interrogation and reply signals; and a receiver (12), connected to said separation means (40), for detecting and decoding said reply signal;

wherein said period is sufficient to allow coherent operation of said oscillator (9) for a period sufficient for said label (4) to transmit at least one complete reply.

37. A system as claimed in claim 36, wherein a portion of the reply code contains identity information and a portion of the reply code contains telemetry information.

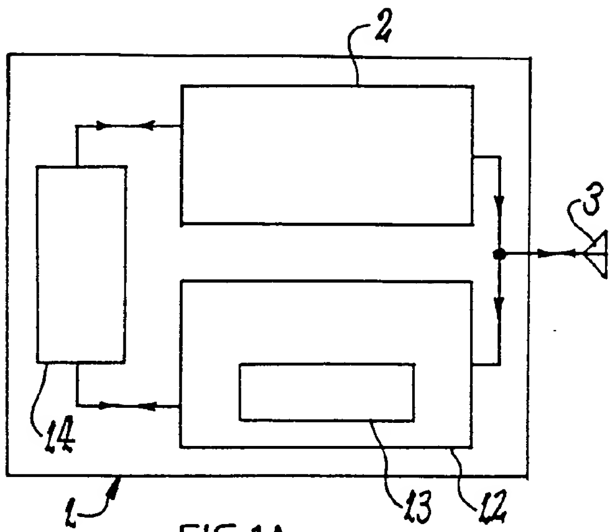


FIG 1A

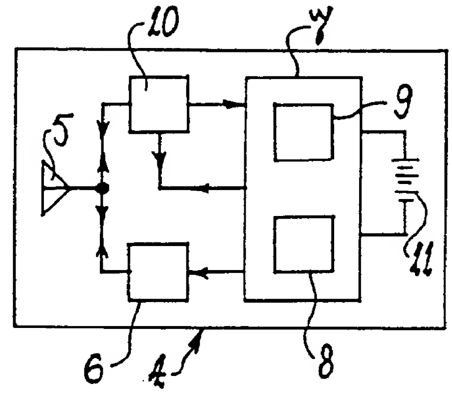


FIG 1B

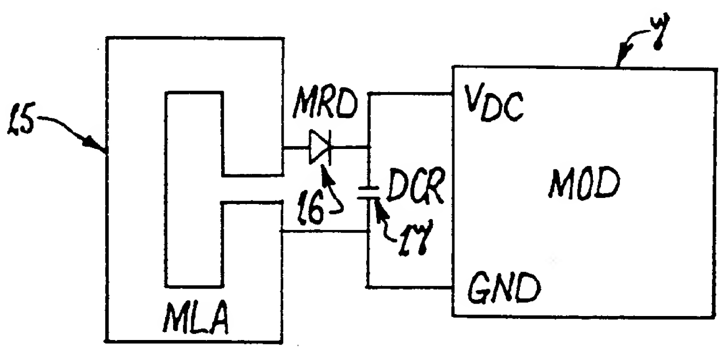
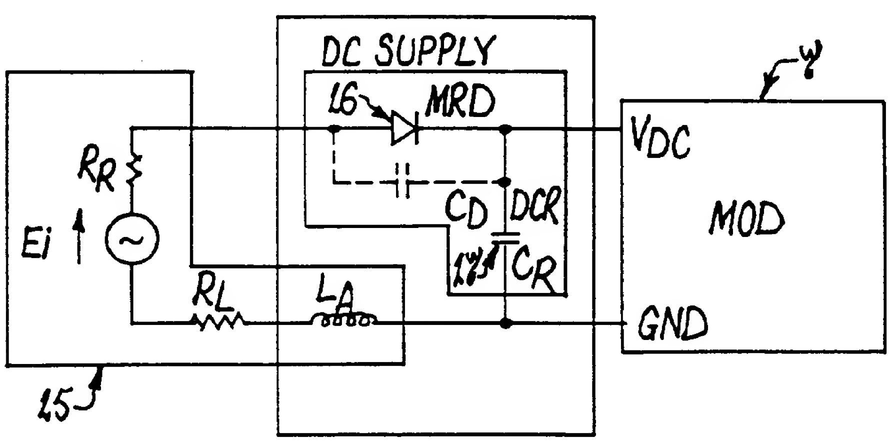


FIG 2A



SERIES RESONANT CIRCUIT

FIG 2B

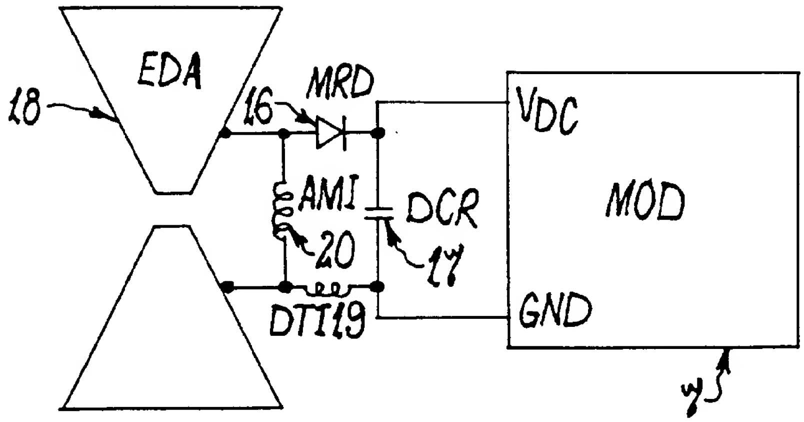
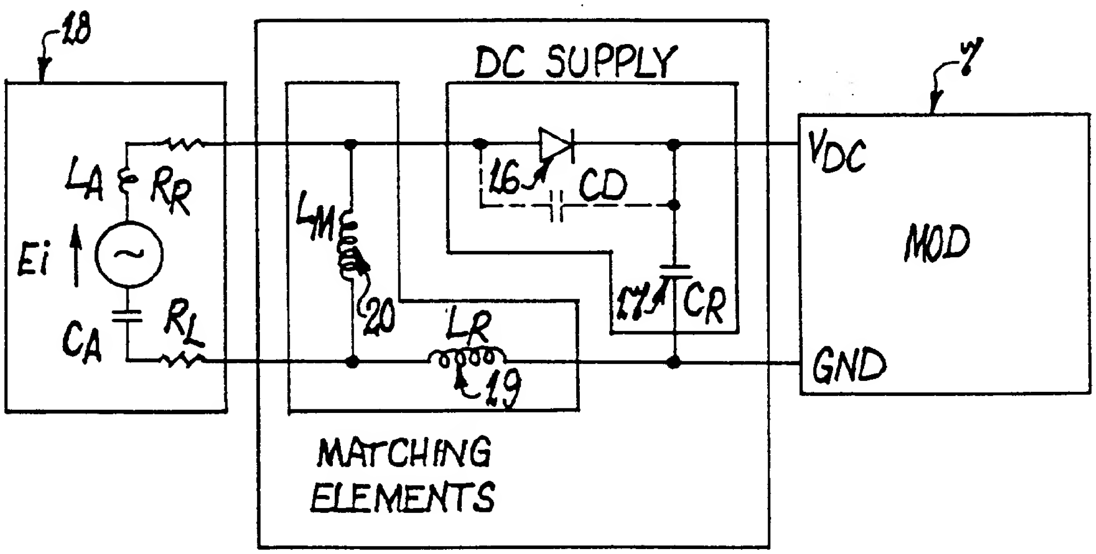


FIG 3A



SERIES RESONANT CIRCUIT

FIG 3B

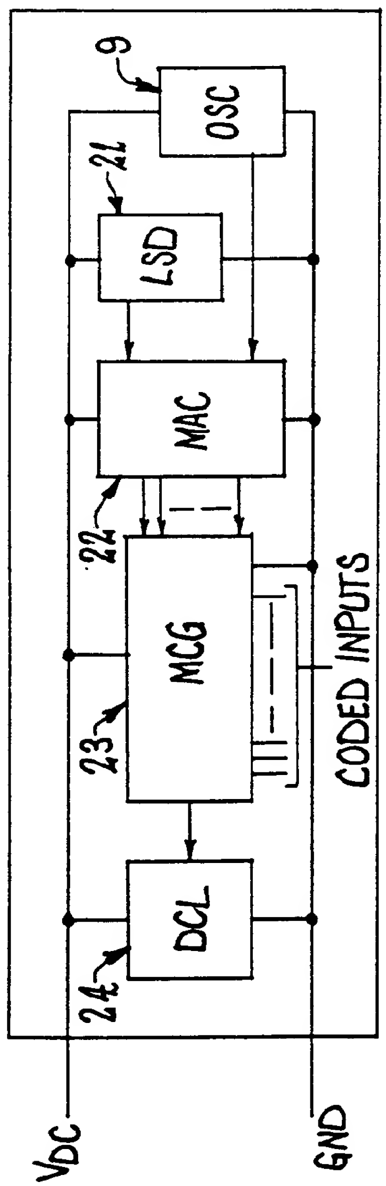

9
OSC
21
LSD
MAC
22
MCG
23
CODED INPUTS
DCL
24
VDC
GND

FIG 4

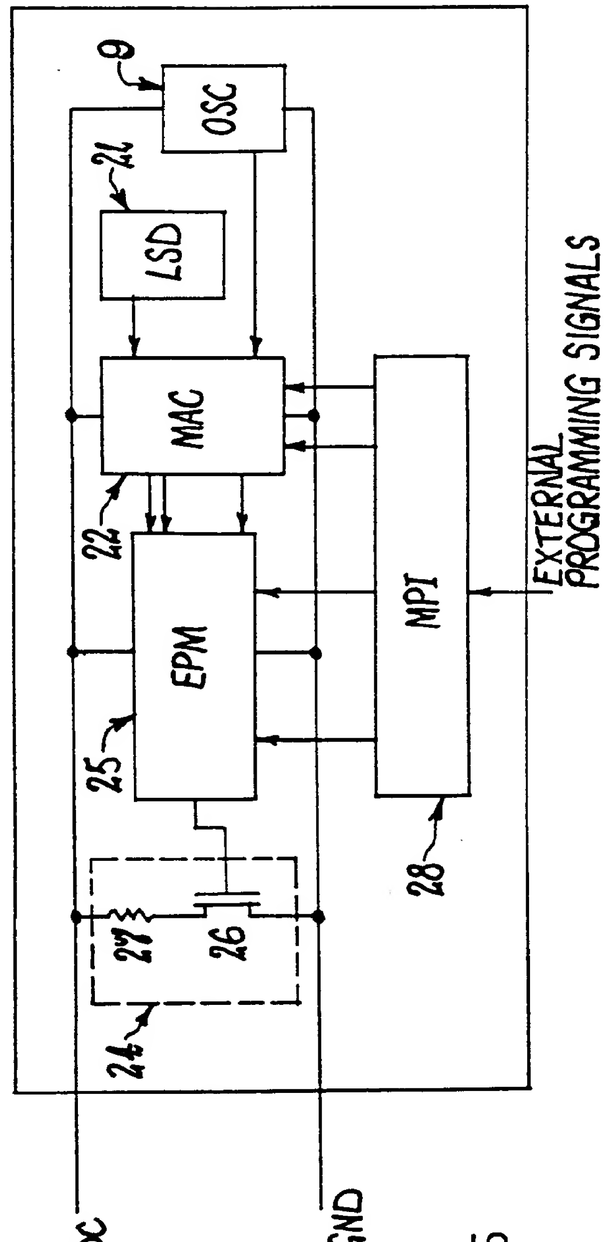

9
OSC
21
LSD
MAC
22
EPM
25
MPI
28
EXTERNAL PROGRAMMING SIGNALS
27
26
24
VDC
GND

FIG 5

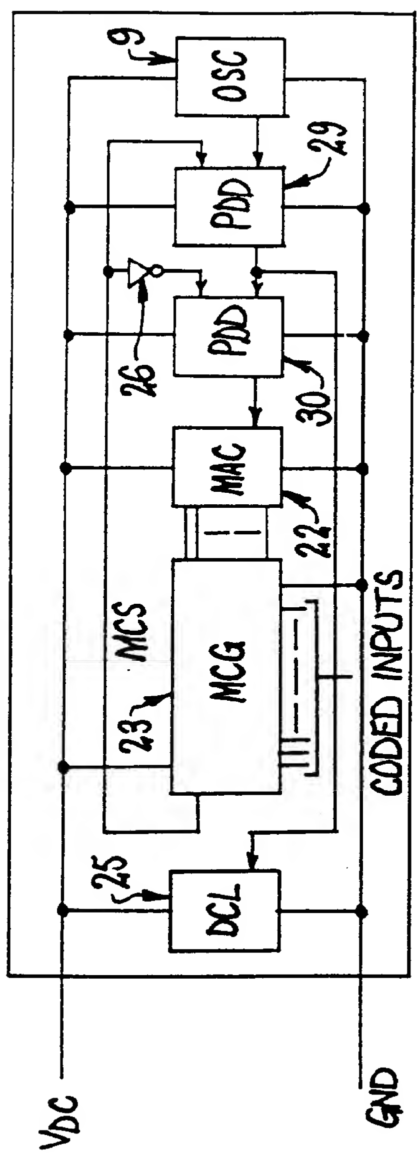


FIG 6

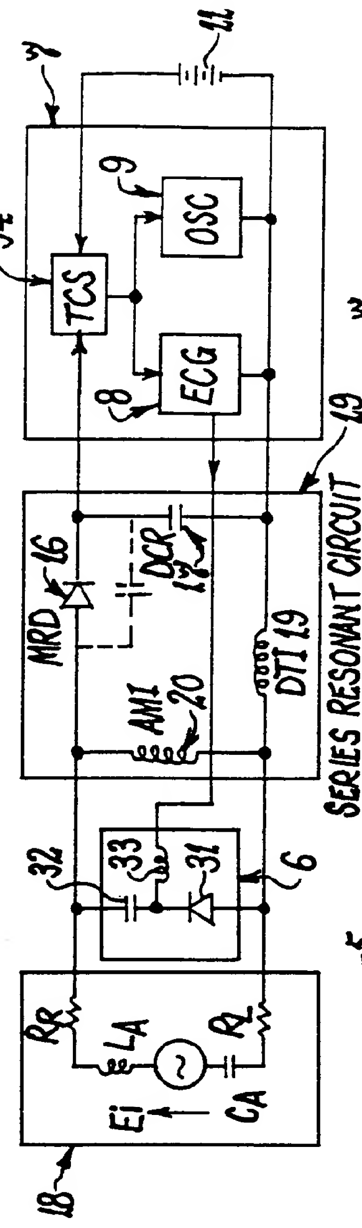


FIG 7

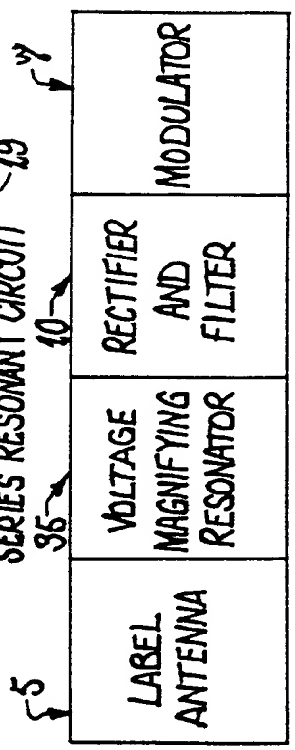


FIG 8

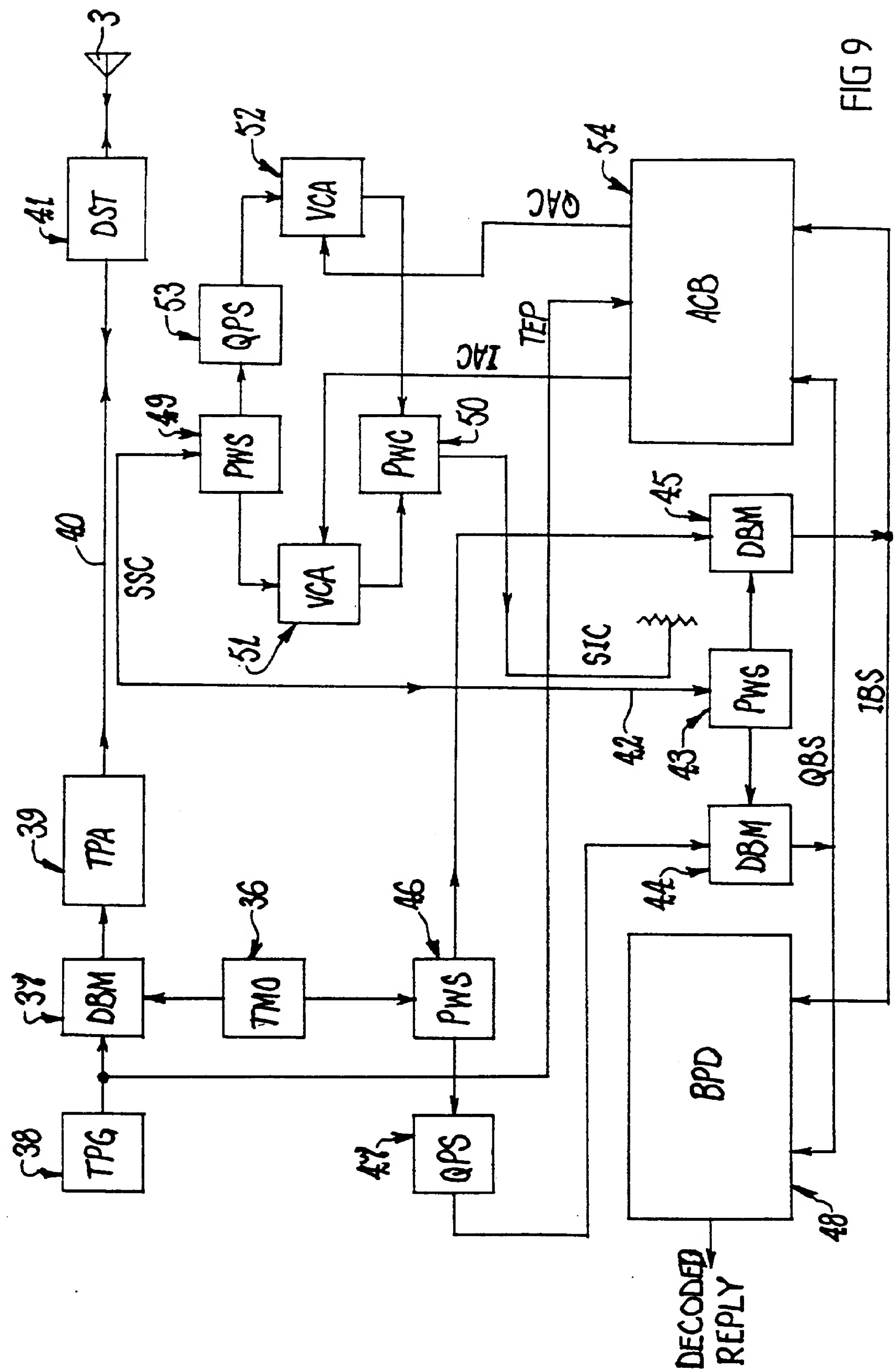

TPG
DBM
TPA
DST
TMO
PWS
QPS
VCA
PWC
ACB
BPD
SSC
SIC
TEP
IAC
QAC
IBS
QBS
DECODED REPLY

FIG 9

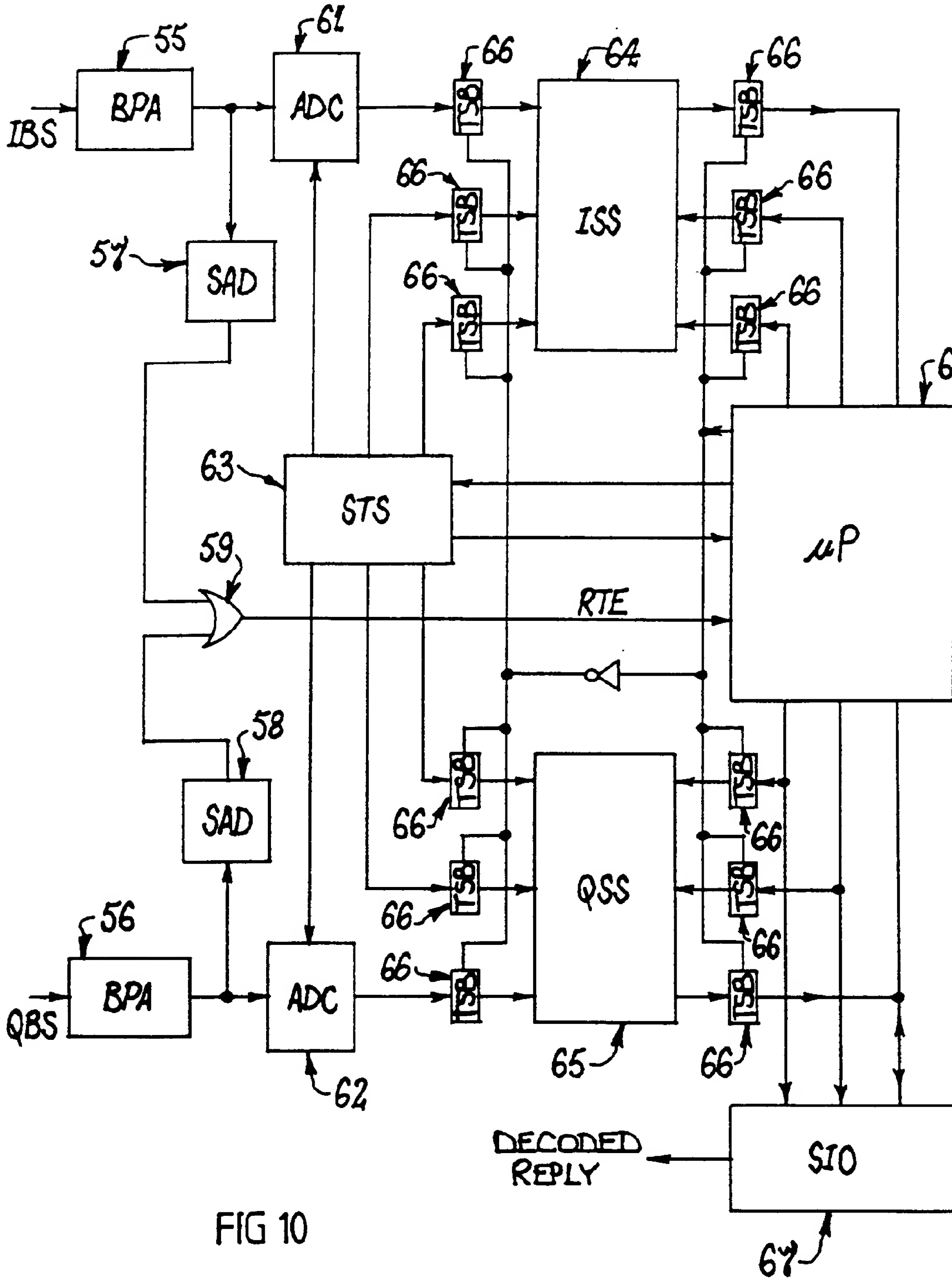

55
BPA
IBS
61
ADC
66
TSB
64
ISS
57
SAD
60
μP
63
STS
59
RTE
58
SAD
QSS
56
BPA
QBS
ADC
62
65
DECODED
REPLY
SIO
67

FIG 10

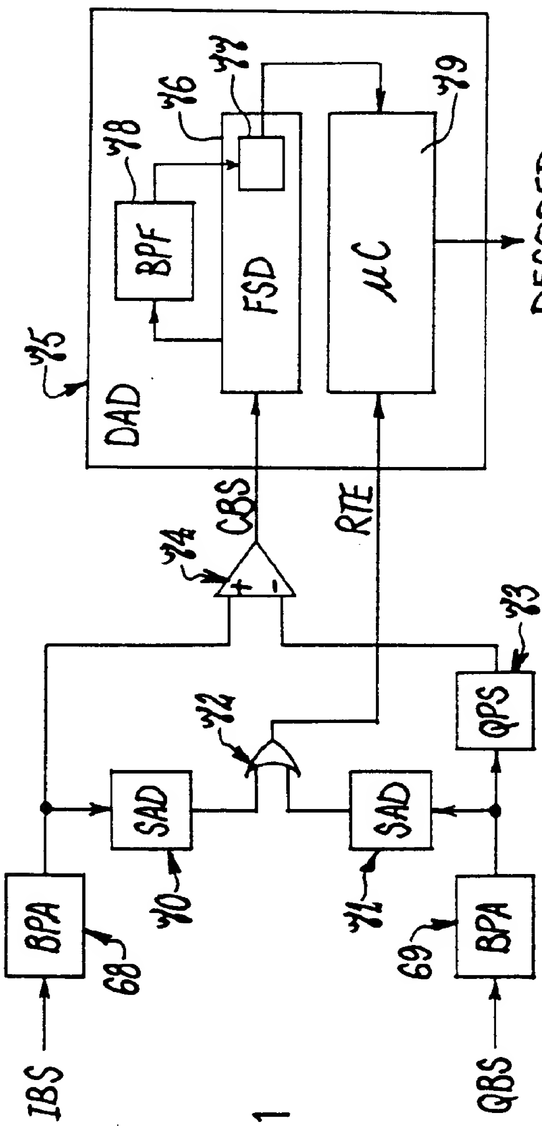

IBS
BPA
68
SAD
70
QBS
BPA
69
SAD
71
72
QPS
73
74
+
-
CBS
RTE
DAD
75
BPF
78
FSD
76
77
μC
79
DECODED REPLY

FIG 11

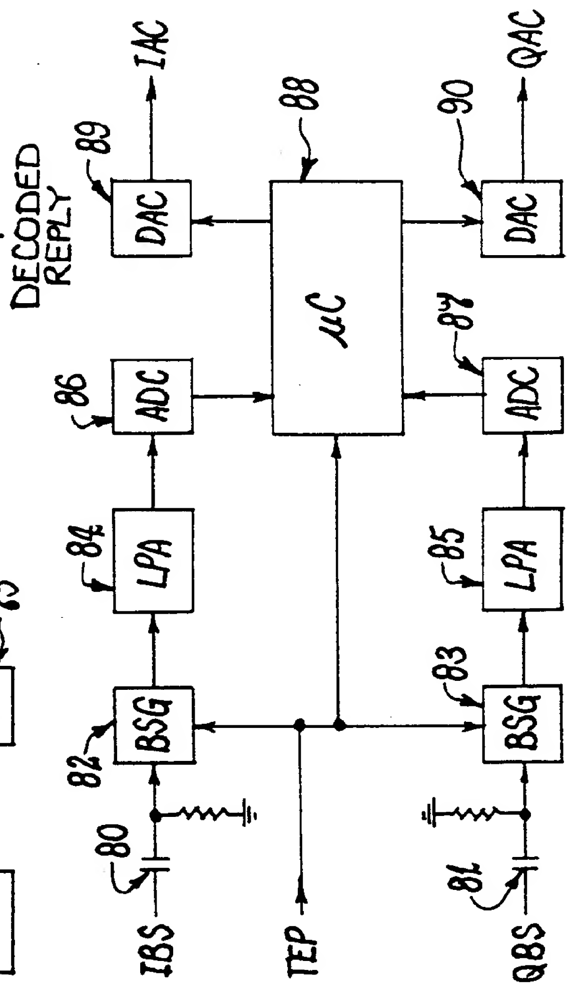

IBS
80
BSG
82
LPA
84
ADC
86
TEP
QBS
81
BSG
83
LPA
85
ADC
87
μC
88
DAC
89
IAC
DAC
90
QAC

FIG 12